Conference Paper

Combined Process for Producing Continuously Cast and Deformed Billets from Technical Copper

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Abstract A foundry-forging module allowing one to obtain a deformed profile of a specified cross section from molten metal in a continuous mode is developed and fabricated. The data of metallography investigations of continuously cast deformed blanks (CCDB) from technical copper and their comparison with structures of cast test samples are given. The results of estimation of the dimensional geometric accuracy of the CCDB samples are presented.

Keywords: continuously cast, deformed billets, foundry-forging module

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Received: 9 September 2016
Accepted: 19 September 2016
Published: 12 October 2016

Publishing services provided by Knowledge E

Selection and Peer-review under the responsibility of the ASRTU Conference Committee.

To obtain continuously cast deformed blanks (CCDB) made from nonferrous metals, we propose the technology and a corresponding set of equipment developed at the Institute of Engineering Science and Metallurgy, Far East Division, Russian Academy of Sciences (Komsomolsk-on-Amur) [1], Their essence lies in combination of three simultaneous processes: continuous cast, liquid stamping, and hot pressure treatment of metals in one facility. The system involves a cast aggregate, a pouring-dosing facility, and a foundry-forging module (FFM) with a controlled driving gear. Two constructive variants of FFM are possible, namely, with vertical or horizontal arrangement of a crystallizer and, correspondingly, with a vertical or a two-side horizontal direction of the output of the CCDB.

Figure 1 shows the layout of the FFM facility with the horizontal arrangement of the crystallizer (FFMG). Preliminarily, prior to pouring the melt into the crystallizer, seeds from a plastic material are placed in its calibrating parts that form the transverse section of the CCDB. They are necessary to provide insularity of the internal cavity of the crystallizer. The latter is heated to the temperature distribution required by the operating regimes. Then molten metal is supplied from the pouring-dosing facility through a heat-resistant pouring nozzle mounted in the windows of wall 4 of the frame and upper wall 5. After filling the crystallizer with the melt, the driving gear of the FFMG is switched on, and the required number of rotations of eccentric driving shafts 3 is established. Then their rotation frequency is adjusted with the melt consumption from the pouring-dosing facility. During rotation of shafts 3, sidewalls of the crystallizer carry out complex motion in the horizontal plane toward each other. This motion is determined by the value of eccentricity, orientation of the eccentrics relative to each

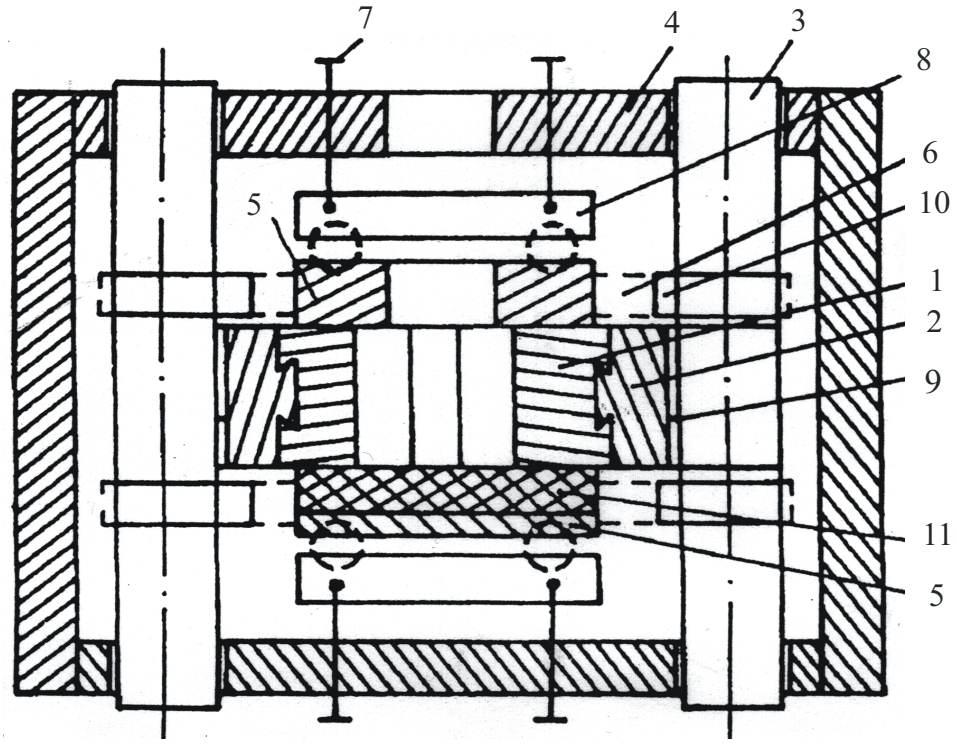

Figure 1: Design of the facility for continuous casting and deformation of metal. (1) Sidewalls, (2) support, (3) driving eccentric shafts, (4) frame walls, (5) upper and lower walls, (6) articulating system, (7) clamping facility, (8) flat ball bearing, (9,10) eccentrics, and (11) insertion from a material with low thermal conductivity.

other, and direction of rotation of the shafts in each side wall, and promotes the deformation of the crystallized metal and alternate motion of the blank toward the output from the calibrating part of the crystallizer. Its upper and lower walls connected only to eccentric shafts 5, during their rotation, are in alternating motion in the horizontal plane, also promoting the alternating motion (self-supply) of the crystallized metal to the output. The driving gear of the upper and lower walls is carried out by eccentrics, which are arranged at the end portions of shafts *3* and are turned by 90° relative to the eccentric of the medium portion, on which support is mounted. Solidification of metal in the crystallizer proceeds owing to heat removal by its movable cooled walls. The variation in parameters of the cooling system allows one to provide the required heat sink in the direction of the crystallizer walls.

Figure 2 shows the appearance of the experimental-industrial FFM facility. The characteristics of quality of the fabricated CCDB samples from Pb-based, Al-based, and Cu-based alloys were the surface hardness and their dimensional geometric accuracy. We compared the structures of the CCDB samples made from technical copper of M1 grade according to GOST (State Standard) 10018-78 and blanks obtained by casting into a metal form (chill mold). The pouring temperature of the melt and the thickness of the CCDB samples and test samples were identical. When fabricating the former, we used the following operating and design parameters: the length and transverse size of a blank were 500 and 30×6 mm^2, respectively; the degree of its reduction in the calibrating part of the FFMG crystallizer was 0.6; the initial temperature in the central

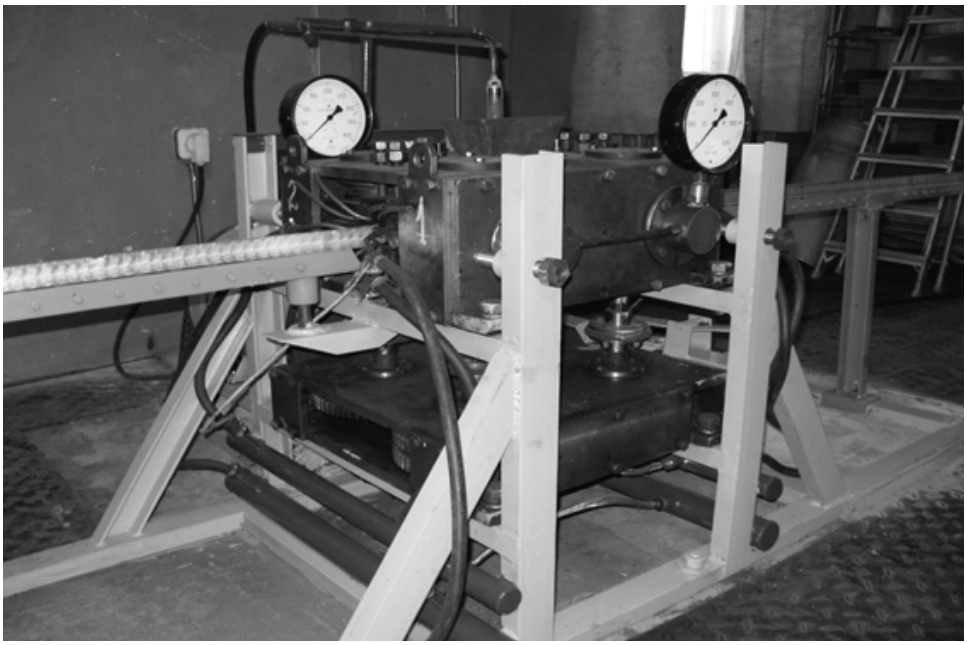

Figure 2: The experimental industrial FFM facility.

part of the crystallizer was 700°C; the pouring temperature was 1150°C; and the output rate of the CCDB was 1.5 m/min.

When investigating the microstructure of test samples, we revealed that, because of the presence of impurities in technical copper, crystallization of the metal proceeds similarly to crystallization of some alloy (Fig. 3). We observed the portions with a coarse-grain and dendrite structure with the presence of inhomogeneity. Dendrite axes are etched more strongly (dark regions) than the interaxial regions (brighter). The first crystallized portions (dendrite axes and coarse grains) constitute the solid solution of copper with dissolved impurities. Impurities virtually insoluble in copper form the low-melting eutectics, which is isolated along l the grain boundaries or forms the interaxial regions. The metal has a structure with various grain sizes, and grains (crystallites) with a chord size from 0.057 to 0.540 mm, sometimes (individual) up to 0.870 mm, are present. The surface hardness of test samples was 76-80 HB.

In the microstructure of the CCDB samples, we also observed two structural components, namely, a solid solution of copper with dissolved impurities, which crystallized as fine grains, and a low-melting eutectic, which is arranged both at the grain boundaries and in the form of coalesced portions. During the hot deformation in the solid-liquid state, the solid solution of copper had already crystallized, while the low-melting eutectic was in the liquid state, which allowed it, when moving under the pressure between the copper crystallites, to form characteristic regions. The presence of reduction at such temperatures is indicated by the presence of deformed grains of the copper-based solid solution elongated in the deformation direction (Fig. 4).

The metal has a structure uniform in grain size with a chord size of 0.019-0.026 mm. The surface hardness of the CCDB samples was 80-90 HB.

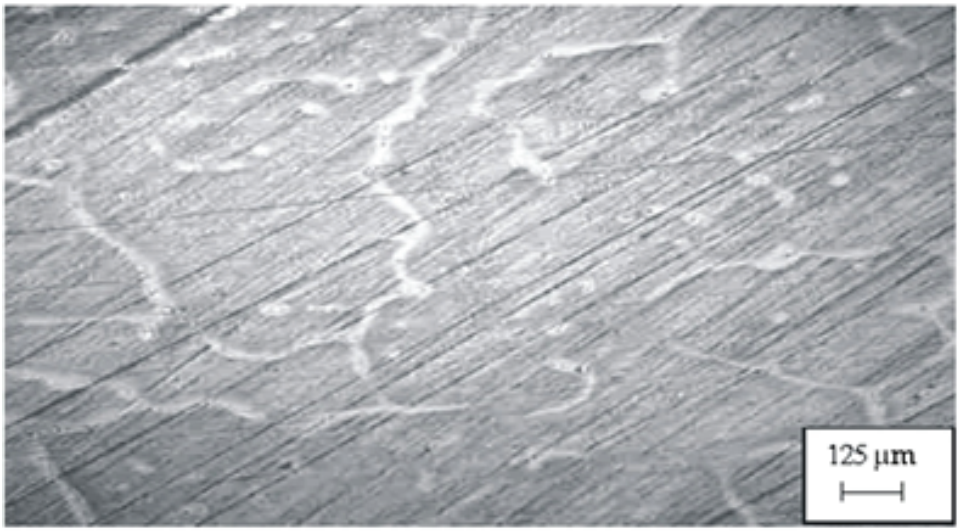

Figure 3: Microstructure of the test sample.

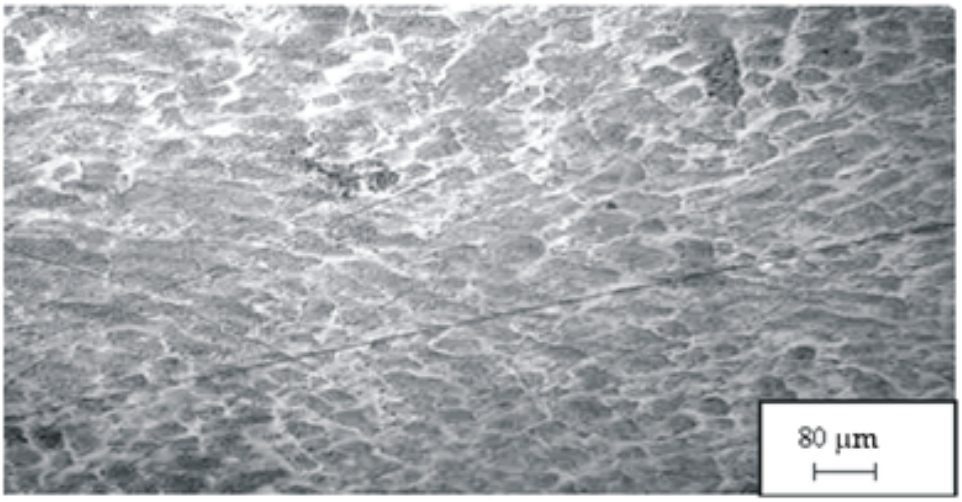

Figure 4: Microstructure of the CCDB sample.

Therefore, the analysis of the structures shows that the grain size of the CCDB samples is considerably smaller than that of the test ones. These grains are more uniformly distributed over the sample cross section, which indicates the higher isotropy of properties of the CCDB samples.

The dimensional geometric accuracy of the CCDB samples of the type of a strip with the transverse cross section 30x6 mm^2 was estimated by deviation of its thickness from the nominal size of the facility. As the latter, we selected the size of the calibrating part of the movable FFM crystallizer. Measurements with a step of 20 mm were carried out along the axial line of the blank. The number of measurement points was no less than 20 over one sample. After statistical processing of the results, the average absolute deviation from the nominal size was 0.18 mm with a confidence level of 0.95. This value corresponds to the third grade of accuracy according to GOST 26645-85 and is characteristic of blanks of a similar standard size that are fabricated by special methods of casting (casting under pressure, liquid stamping).

Thus, it is revealed from the analysis of the structures that the grains of the CCDB samples are considerably smaller than those of the test samples. These grains are distributed more uniformly over the sample cross section, which indicates the higher uniformity of properties of the CCDB samples. Their dimensional geometric accuracy corresponds to the accuracy of blanks of a similar standard size that are fabricated by special methods of casting.

References

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